REFRACTION OF THE EYE

MORTON.

SIXTH EDITION

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REFRACTION OF THE EYE

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ITS

DIAGNOSIS

AND THE

CORRECTION OF ITS ERRORS

BY

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PREFACE

TO THE SIXTH EDITION.

WITHOUT materially altering the subject-matter of this little book, the issue of a new edition affords the opportunity of revising and amplifying some points in the work which appeared to require further elucidation.

Harley Street, W.,
December, 1896.

PREFACE

TO THE FIRST EDITION.

THESE notes are published with a view of enabling Practitioners to diagnose and correctly estimate the value of the phenomena indicating the state of a patient's refraction. They are intended to furnish a basis for observation, and it is hoped that they will make evident the necessity which exists for *personally working out* a large number of refraction cases in order to acquire anything like proficiency in prescribing correct glasses.

To those friends who have aided me by their suggestions I would take this opportunity of expressing my best thanks.

March, 1881.

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REFRACTION OF THE EYE

INTRODUCTION.

THESE pages have been written in the hope that they may be of service to beginners, and to physicians and general practitioners, who, systematically using the ophthalmoscope in their investigation of disease, must avail themselves of the information thereby afforded regarding the patient's refraction, in order that due allowance may be made for any error which exists. If patients can assist by their answers, much valuable information is afforded by the use of test-types and glasses, a description of which, with the information to be derived therefrom, has been therefore introduced.

Information is given on the subject of the glasses required in the more *ordinary* cases, but for a knowledge of the various diseases which accompany and complicate many of the errors of refraction, the reader is referred to the works already published on that subject, to the study of which these notes are intended to prepare the way.

So essential is a constant remembrance of some of the facts hereafter mentioned, that, at the risk of tautology, they have been kept constantly before the reader. The plan which has been found so useful in other branches of medical study has been adopted here—viz., that of working out from the symptoms the nature of the disease in preference to the method of naming the disease and then describing the symptoms accompanying it.

In making an estimation of the refractive character of an eye, it is especially necessary to proceed *systematically*. On a patient complaining of "bad sight" the vision of each eye must always be tested separately, and we should examine him somewhat in the following manner:

1. Listen carefully to the nature of his complaint.
2. Test the near and distant vision *without* glasses.
3. Estimate the refractive character of the eye by either
    (*a*) Ophthalmoscopy,
    (*b*) Retinoscopy;

both of which are *objective* methods.

4. Examine the eye with an ophthalmoscope in order to ascertain whether any lesion other than that of refraction exists.
5. Test the distant and near vision with the glasses for whose use the previous examination has indicated the necessity.

Two methods of notation are at present in vogue (*vide* Chap. III.). The new system of numeration is the one which is now almost universally employed, and it has been adopted in the text. The *approximately* corresponding measurements in English inches have, however, been given in brackets for the convenience of those who prefer the old method.

Only so much ophthalmoscopy has been introduced as was necessary to explain the phenomena of refraction.

CHAPTER I.

Action of Rays and Lenses.

(*a*) Rays of light issuing from every point of any object diverge in *all* directions. The nearer an eye is to such an object, the more of its *di*verging rays does it intercept; and, *vice versa*, the further the eye is removed, the fewer are the divergent rays which reach it—*i.e.*, the more parallel are the rays which enter it. Only from objects at an infinite distance do we receive absolutely parallel rays.

For practical purposes, however, we may *consider* those rays to be parallel which proceed from an object situated at a distance of 6 m. (20 ft.) or more.

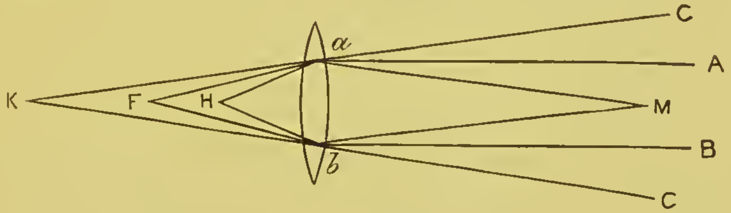

Fig. 1.

(*b*) Parallel rays (Fig. 1, A*a*, B*b*) passing through a convex spherical lens come to a focus at a point F, on the other side of the lens. This point is called the "principal focus" of the lens, and the distance from this point to the centre of the lens is named "the focal distance" or "focal length" of the lens. Conversely, rays proceeding from a point situated at the principal focus of the lens emerge parallel to each other.

(*c*) *Diverging* rays (Fig. 1, M*a*, M*b*), after traversing such a lens, unite at a point K, which is situated further from the lens than the principal focus. Conversely, rays proceeding from a point further from the lens than its principal focus, after passing through it, emerge as convergent rays.

(*d*) *Converging* rays (Fig. 1, C*a*, C*b*), after traversing a convex lens, meet at a point H, which is nearer to the lens than its principal focus. Conversely, rays from a point situated nearer to the lens than the principal focus are, on emerging from the lens, still divergent, though less so than before passing through it.

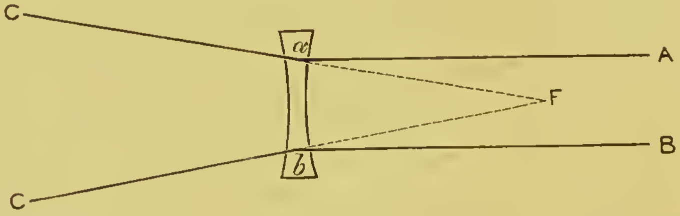

FIG. 2.

(*e*) *Parallel* rays (Fig. 2, A*a*, B*b*), after traversing a concave spherical lens, *di*verge (*a*C, *b*C) as if proceeding from a point F (" the virtual focus ") situated on the *same* side of the lens as that from which the parallel rays proceed. The distance of this point from the lens is the " negative focal length " of the lens. Conversely, rays which converge as if proceeding to this point are rendered parallel by passing through it.

(*f*) A cylindrical lens influences the course taken by rays of light in the same manner as a spherical, but acts most on those proceeding in a direction at *right angles* to its axis.

(*g*) By the *refraction* of a lens is meant the property which it possesses of altering the direction of rays traversing it.

(*h*) The refracting *power* of a lens is indicated by the distance from it of the point at which parallel rays traversing it meet, *i.e.*, by its focal distance. The greater the focal distance, the less is its refracting power, and *vice versâ*.

CHAPTER II.

Definitions.

Def. 1.—The refracting surfaces of the eye are, according to Donders, (*a*) the anterior surface of the cornea; (*b*) the anterior surface of the lens; (*c*) the anterior surface of the vitreous. The transparent media together form the *dioptric system* of the eye, which influences the course taken by rays of light traversing it in a manner very similar to a biconvex lens.

Def. 2.—*Refraction of the eye* means the effect which, by reason of its form and structure, this organ produces upon rays of light entering it when the action of the accommodation apparatus is completely suspended.

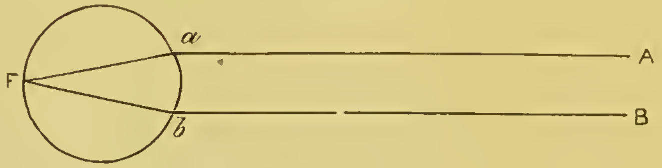

Fig. 3.

Def. 3.—In *emmetropia* (Fig. 3) parallel rays A*a*, B*b* come to a focus *upon* the retina F, when there is no accommodation. Conversely, rays proceeding from points in the retina emerge from the eye parallel to one another.

Def. 4.—An *ametropic* eye is one in which, when there is no accommodation, parallel rays do *not* come to a focus upon the retina. Such an eye may be either myopic, hypermetropic, or astigmatic.

DEF. 5.—A *myopic* eye (Fig. 4) is that in which, when there is no accommodation, parallel rays come to a focus in *front* of the retina, as at F. Conversely, rays issuing from the retina R, which is behind the principal focus of the dioptric system, emerge as convergent rays (Chap. I., *c*) which meet at a point M in front of the eye. Rays proceeding from this point (called the "far point") would therefore be focussed on the retina.

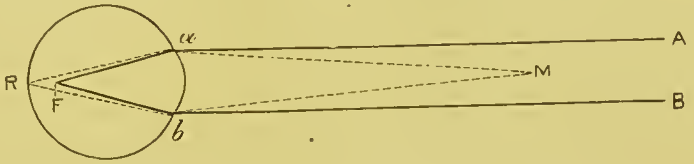

FIG. 4.

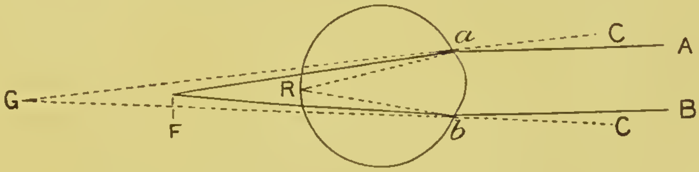

FIG. 5.

DEF. 6.—A *hypermetropic* eye (Fig. 5) is that in which, when there is no accommodation, parallel rays (A*a*, B*b*) are so changed in direction that they tend to come to a focus at F, *behind* the retina. Conversely, rays proceeding as if from F would emerge from the eye parallel to one another. Rays, therefore, from R, which is situated *within* the focus of the dioptric system (*vide* Def. 1), emerge from the eye diverging (Chap. I., *d*) as if they were proceeding from a point G.

The distance of this point behind the front part (nodal point) of the eye will, in any case, be equal to the focal length of the convex lens, which, when held close to the eye with its accommodation suspended, would bring parallel rays to a focus on the retina. For, since the rays from the retina on emerging from the eye diverge as if they issued from G, it follows that rays converging as if proceeding to G would meet on the retina at R. Consequently, the convex lens which, with the aid of the dioptric system of the eye, brings parallel rays to a focus at R, would, without the aid of that system, bring them to a focus at G. This latter point is therefore at the principal focus of the lens (*vide* Chap. I., *b*).

DEF. 7.—A *regularly* astigmatic eye is that in which there is a difference in the degree of refraction in different meridians; the two *principal* meridians (that is, the meridians of greatest and least error) being always at *right angles* to each other.

"Regular astigmatism" may exist in five different forms:

(*a*) Simple myopic = one principal meridian emmetropic, the other myopic.
(*b*) Simple hypermetropic = one principal meridian emmetropic, the other hypermetropic.
(*c*) Compound myopic = both principal meridians myopic, one more than the other.
(*d*) Compound hypermetropic = both principal meridians hypermetropic, one more than the other.
(*e*) Mixed = one principal meridian myopic, the other hypermetropic.

DEF. 8.—An *irregularly astigmatic* eye is one in which there are different degrees of refraction in different parts of the various meridians.

DEF. 9.—A *presbyopic* eye is that in which the power of accommodating for near objects is lost, owing to physiological changes produced by advancing age, and there is, consequently, an inability to define small objects situated near to the eye (*vide* Presbyopia, Chap. XII.). It may co-exist with any of the above-named conditions.

DEF. 10.—*Anisometropia* is a term used to denote that the refractive condition of one eye differs from that of the other.

From the statements in this and the preceding chapter the following deductions may be made:

Deduction 1.—In order that *parallel* rays may be brought to a focus on the retina of a myopic eye, they must be made to diverge as if they proceeded from the far point (Def. 5, p. 7). This is effected by placing before the eye and close to it the concave lens whose negative focal length equals the distance of this point from the eye (Chap. I., *e*). The amount of the myopia is said to be equal to the refracting power (Chap. I., *h*) of this lens.

Deduction 2.—In order that *parallel* rays may be brought to a focus on the retina of a hypermetropic eye at rest, they must be made to converge as if they proceeded to the point behind the eye from which retinal rays appeared to issue (Fig. 5, G, p. 7). This is effected by placing before and close to the eye a biconvex lens whose focal length is equal to the distance of that point from the front of the eye. The *amount* of the hypermetropia is said to be equal to the refracting power of this lens.

Deduction 3.—In regular astigmatism one principal meridian is corrected by a cylindrical lens. Correction of both requires a bi- or spherico-cylindrical lens.

CHAPTER III.

Old and New Systems of Measurement.

In the old system the unit of measurement was a lens whose focal length or refracting power was 1 inch.

Such a strong lens did not, however, exist in the trial cases, and consequently the numbers of the lenses were expressed by some fraction ($\frac{1}{2}$, $\frac{1}{10}$, etc.) indicating how much their refracting power was less than the lens whose focal distance was 1 inch.

The denominator of the fraction indicated in inches the focal distance of any given lens.

It will thus be seen that the lenses whose focal distances were 6 inches and 12 inches had respectively $\frac{1}{6}$ and $\frac{1}{12}$ the refracting power of the lens whose focal distance was 1 inch. The intervals between the lenses were irregular, and the difference between the refracting powers of any two lenses had to be calculated by means of fractions.

In the new or "dioptric" system the unit of measurement is a lens whose focal distance or refracting power is 1 metre or "dioptre," = 1 D. If two such lenses were placed together they would have twice the refracting power of this unit with half its focal distance.

A lens, therefore, having a refracting power equal to two such units is expressed as 2 D., and has a focal distance of

50 cm. In the same way a lens equal in refracting power to ten such units = 10 D., and its focal distance is one-tenth of that of the unit (= 10 cm.). Further, a lens whose refracting power is only half that of the unit = ·5 D., and has twice the focal distance of the unit, viz., 200 cm.

The dioptric system of notation has now almost universally superseded the other system, because the intervals between the lenses are regular, and the calculations are made in *whole numbers* instead of fractions.

The focal length of any lens can be instantly estimated. Thus, a division of the number of the lens in dioptres (D.) into 100 gives the focal length of the lens in centimetres. Conversely, the division of the focal length (in centimetres) of any lens into 100 gives the strength of the lens in dioptres.

In order to ascertain the corresponding numbers in the two systems for any lens, we must remember that 1 dioptre (or metre) = 37 Paris inches and (39·4) nearly 40 English inches, and that, therefore, the lens with 1 D. focal length corresponds to the lens in the old series whose focal length is 40 in. ($\frac{1}{40}$); 2 D. to a lens with double this refracting power, or $\frac{2}{40}$ ($\frac{1}{20}$) of the old, and so on.

Where *d*, then, represents the number of dioptres, and *a* the number of inches, we can ascertain (1) the lens in the old series which corresponds to one of the new by the formula $\frac{d}{40} = \frac{1}{a}$; and (2) the number of a lens in the new system corresponding to one in the old by the formula $d = \frac{40}{a}$.

The following table gives the lens which, in an ordinary

French or English trial case, will correspond *most* nearly with any given dioptre.

For greater accuracy in any special case the reader must calculate according to the formulæ given above.

TABLE I.

D.	Focal length in English inches.	Focal length in Paris inches.	Focal length in centimetres.	D.	Focal length in English inches.	Focal length in Paris inches.	Focal length in centimetres.
0·25	160	144	400	5·0	8	7	20
0·50	80	72	200	5·50	7½	6½	18
0·75	50	50	133	6·0	7	6	16
1·0	40	36	100	7·0	6	5	14
1·25	30	30	80	8·0	5	4½	12·5
1·50	24	24	66	9·0	4½	4	11
1·75	22	20	57	10·0	4	3¾	10
2·0	20	18	50	11·0	3½	3½	9
2·25	18	16	44	12·0	3¼	3	8·3
2·50	16	14	40	13·0	3	2¾	7·6
2·75	14	13	36	14·0	2¾	2½	7·1
3·0	12	12	33	15·0	2¾	2½	6·6
3·50	11	10	28	16·0	2½	2¼	6·2
4·0	10	9	25	18·0	2¼	2	5·5
4·50	9	8	22	20·0	2	1¾	5

CHAPTER IV.

ACCOMMODATION.

DEF. 11.—By "the accommodation of the eye" is meant the power which we possess of bringing to a focus on the retina rays proceeding from objects situated at various distances. These distances range between the far point and the near point. The far point (punctum remotum, p.r.) is the point for which the eye is adjusted when the accommodation is totally suspended, and the near point (punctum proximum, p.p.) is the point for which the eye is adjusted when the whole of the accommodative power is called into activity. The amount of accommodation thus exercised by an eye in passing from a condition of extreme relaxation to a condition of maximum tension is called the *range* or *amplitude* (Donders) of accommodation. This amplitude may be represented by the convex lens, which, with completely suspended accommodation, would bring rays proceeding from the near point to a focus on the retina.

Now, a biconvex lens whose focal length equals the distance of the near point from the eye will, when placed close to an eye, render *parallel* the rays entering that organ from its near point (*vide* Chap. I., *b*).

Since in *Emmetropia* (E.), when the eye is at rest, *parallel* rays come to a focus on the retina (Def. 3, p. 6), such a lens represents in E. the amplitude of accommodation.

But in *Hypermetropia* (H.), when the eye is at rest, *parallel* rays do *not* come to a focus on the retina without the aid of a convex lens (Chap. II., Deduct. 2). In order to estimate the amplitude of accommodation in this case, the strength of the lens necessary to render the parallel rays sufficiently convergent must therefore be *added* to that of the lens whose focal length equals the distance of the near point from the eye. Thus, if the H. = 3 D. ($\frac{1}{12}$), and the near point = 14 cm. (6 ins.), then, to the lens whose focal length = 14 cm., viz., 7 D. ($\frac{1}{6}$) we add that which brings parallel rays to a focus on the retina, viz., 3 D. ($\frac{1}{12}$). The amplitude, therefore, will be 7 D. + 3 D. = 10 D. ($\frac{1}{6} + \frac{1}{12} = \frac{1}{4}$).

From this it will be seen that, with the *same* amplitude of accommodation, the near point is *further* from the eye in H. than in E.

In *Myopia* (M.), since a concave lens is necessary to effect the focussing of parallel rays on the retina (Chap. II., Deduct. 1), it is evident that in order to estimate the amplitude of accommodation, the strength of the lens requisite to render parallel rays sufficiently divergent to come to a focus on the retina must be *deducted* from that of the lens whose focal length equals the distance of the near point from the eye. Thus, if the M. = 3 D. ($\frac{1}{12}$), (*i.e.*, p.r. = 33·3 cm.), and the near point = 7·6 cm. (3 ins.), then, from the lens whose focal length = 7·6 cm., viz.; 13 D., we must *deduct* that which brings parallel rays to a focus on the retina, viz., 3 D. ($\frac{1}{12}$). The amplitude, therefore, will be 13 D.—3 D. = 10 D. ($\frac{1}{3} - \frac{1}{12} = \frac{1}{4}$). From this we see that, with the *same* amplitude of accommodation, the near point is *closer* to the eye in M. than in E.

It is further evident that, if the near point had been the *same* for each of the foregoing examples, the amplitude would have been greater in H., and less in M., than in E.

As age advances the near point recedes further from the eye, so that in *presbyopia* there is an *absolute* diminution of the amplitude. The amount of the diminution varies with the age of the individual. If the near point recedes until it reaches the far point, the accommodation of course becomes *nil.*

CHAPTER V.

PERCEPTION OF A LINE.

THE distinctness with which a line is visible depends upon the sharp and well-defined perception of its *margins* ; if these are indistinct the line appears hazy. A line may be taken as made up of an infinite number of elements or points, from each of which rays issue in all directions. To gain a distinct image of any line, it is necessary that the rays from these points, which emerge in planes at *right angles* to its long axis, should be brought to a focus at points on corresponding planes on the retina, otherwise circles of diffusion are formed in this *transverse* direction of the line, which overlap each other, and finally, by projecting beyond its margins, give to it an ill-defined and blurred outline, so that no distinct perception of it is obtained. If from these same points the rays emerging in planes *parallel* to the long axis overlap each other, it is only at the two extremities of the line that, by projecting, they cause any blurring. The margins of the line thus not being in any way affected, there is no interference with the outline, and a clear image is formed on the retina.

If, then, a patient with his accommodation suspended, and who is emmetropic in one meridian, and myopic or hypermetropic in the other, be placed at 6 m. (20 ft.) from radiating lines of equal definition, he will see most *distinctly* that line which runs at *right angles* to his *emmetropic* meridian. Rays from points in the transverse planes of this line will, by passing through the emmetropic meridian, come to a focus on his retina, giving a distinct, well-defined image of the margins, and hence a clear perception of the line. The line *parallel* to the emmetropic meridian will, at the same time, be the most *in*distinct. Rays from *its* transverse planes pass through the myopic or hypermetropic meridian. They thus come to a focus, in the former case in front of, and in the latter behind, the retina, producing circles of diffusion in these planes, and a consequent blurring of the margins of the line, so that no distinct image is obtained.

RULE I.—We have, then, the rule that, in *simple* astigmatism, the patient at 6 m. sees *most distinctly* the line *parallel* to the plane of his *error of refraction*.

It follows, also, that a patient with either compound or mixed astigmatism will not see *any* line distinctly at 6 m. when his accommodation is suspended.

CHAPTER VI.

Description of Test-Types: Method of Employing them.

Test-types are divided into: (*a*) Those adapted for ascertaining *near* vision; and (*b*) those adapted for ascertaining *distant* vision. In using them, we are obviously dependent on the answers given by the patient. For children, illiterate adults, and impostors, they are therefore an inferior means of diagnosing and estimating the refractive condition of an eye.

(*a*) TEST-TYPES FOR NEAR VISION.

Those generally in use for this purpose are Jaeger's or Snellen's. The latter are so graduated that each should be read *as far off* as the distance for which it is marked. The smallest should be seen at a distance of 50 cm. (18 ins.), and the largest at 4 m. (12 ft.). These types are given into the patient's hand, and we then note the smallest he can read, and also the nearest and the farthest points at which it is distinctly visible. The small types are chiefly useful in testing the accommodation, but they also afford an indication of the presence and amount of myopia (*vide* Chap. XII., Myopia).

The wire optometer is perhaps the best means of ascertaining the position of the near point.

(*b*) TEST-TYPES FOR DISTANT VISION.

Snellen's types for this purpose are so graduated that each should be distinctly legible *as far off* as the distance for which it is marked. The largest should be seen at 60 m., and each succeeding line at 36, 24, 18, 12, 9, and 6 m. respectively. The corresponding lines in the old system were of such a size as to be legible at 200, 100, 70, 50, 40, 30, and 20 ft. respectively. Those who were accustomed to the old system, but who now use the new metrical type, still speak of the second, third, and fourth lines as if they were to be read at 100, 70, and 50 ft. respectively, and they are therefore thus referred to in these pages, though these distances do not absolutely correspond to the distances at which these lines are meant to be read. The distances at which the rest of the lines are to be read correspond exactly in the two systems. The size of these types is such that anyone with fairly good vision can read them, and consequently many young Emmetropes can see them clearly at a distance greater than that for which they are marked.

In testing with these types, we place the patient at such a distance that rays issuing from them reach his eye as parallel rays. For *practical* purposes, this is obtained at a distance of 6 m. (20 ft.)—*vide* Chap. I., *a*—from which point the lowest line should be read by the normal eye without accommodation; and in these pages this is the distance at which the patient is always assumed to stand. By many, however, 5 m. (16 ft.) is considered to be a sufficient distance. For testing astigmatism, some use a fan of radiating lines all of the same magnitude and definition. These should all appear equally distinct to the normal eye at 6 m. In noting the vision (V.), we employ a fraction whose numerator denotes the distance at which the patient stands, and whose denominator indicates the lowest line which he can read. The number of the line is designated by the distance in metres (or feet) at which it *should* be legible. Thus, normal V. $=\frac{6}{6}$ $(\frac{20}{20})$, or 1; but if at 6 m. (20 ft.) the patient read only the line which *should* be read as far off as 12 m. (40 ft.), we say V. $=\frac{6}{12}$ $(\frac{20}{40})$, or $\frac{1}{2}$. Seeing that our object in testing refraction is always to have the accommodation suspended, we should not place the patient nearer the types than 6 m. If it be necessary, however, in defective V. *from other causes*, we may allow him to approach the types till he can read the largest; if this be at a distance of, say, 2 m. (6 ft.), then V. $=\frac{2}{60}$ $(\frac{6}{200})$.

Dr. Snellen's test-types may be obtained from Messrs. Williams and Norgate, Henrietta Street, Covent Garden; but some types corresponding to those arranged by him have, by his kind permission, been introduced at the end of this book for purposes of illustration. The number over each type indicates in metres and feet the distance at which it should be legible; and in the types for testing near vision the figure in the right-hand corner denotes the approximately corresponding number of Jaeger's type.

CHAPTER VII.

INDICATIONS AFFORDED BY USE OF TEST-TYPES.

NOTE.—In the following section the patient is tested *without* glasses, then :

Indication 1.—If a patient read Jaeger 1 (J. 1) or Snellen 1 (Sn. 1) with a good range, and read also $\frac{6}{6}$ ($\frac{20}{20}$) perfectly, he is probably *emmetropic.* He cannot be myopic, though he may be hypermetropic or somewhat astigmatic; for a hypermetropic or slightly astigmatic patient with active accommodation could accomplish this.

Indication 2.—If a patient *over forty years of age* read only the larger J. or Sn. types (or perhaps even the smaller), but only on condition that he holds them at a considerable distance, while at the same time he can read $\frac{6}{6}$ ($\frac{20}{20}$) perfectly, he is probably simply presbyopic.

Indication 3.—If a patient must hold the types *close* to his eye, but can then read even the *finest*, though he cannot see $\frac{6}{60}$ ($\frac{20}{200}$), he is *myopic.*

NOTE.—A patient may read Sn. 1 as far as 50 cm. (18 ins.), or even Sn. 2 as far as 60 cm. (2 ft.), together with some of the larger distance types, such as $\frac{6}{36}$ ($\frac{20}{100}$). In this case he is *very slightly myopic.* N.B.—Since such a patient can read Sn. 1 up to within a short distance from his eye, he is thus easily distinguished from the following :

Indication 4.—If a patient read only the larger series of the small types, and the smaller series not at all, or only very imperfectly, while at the same time the distant vision is very defective, we suspect either some form of *astigmatism* or *hypermetropia without accommodation.*

In a patient *under* forty years of age it is probably the former, but in one *over* that age it may be *either*, though it is frequently only the latter condition which exists.

Indication 5.—If a patient *under* forty or forty-five can read only such large types as Sn. for 4 m. (J. 16), while he can read $\frac{6}{6}$ ($\frac{20}{20}$), he has *paralysis of accommodation.* This may be proved by giving him a strong convex lens, such as + 3 D. (12 ins.), when he will read Sn. 1 or J. 1 at the focal distance of the lens. (Chap. IV., p. 13.)

Indication 6.—If a patient whose accommodation is suspended see quite distinctly *one only* of the radiating lines at 6 m., he is *emmetropic* only in the meridian at *right angles* to this line, and either hypermetropic or myopic in the other. (Chap. V., p. 16.)

CHAPTER VIII.

INDICATIONS AFFORDED BY MEANS OF MIRROR ALONE.

"DIRECT METHOD."

IN order that the indications of the refraction afforded by this method may be realized, the observer, if he be not emmetropic, must correct any error of his own refraction by means of spectacles or of a lens placed behind the sight-hole of the mirror. He should then seat himself opposite to and 3 or 4 ft. away from the patient, who is to gaze steadily at the darkened wall in front of him, looking towards the left side of the observer's head when the left eye is under examination, and *vice versâ* when the right is examined. By this means the optic disc is brought into the axis of vision of the observer. The latter must now throw the light from his mirror into the patient's eye, and, keeping the fundus illuminated, should move his head in various directions.

Indication 1.—If he then see nothing more than the red reflex of the fundus, or at most a *blurred* image of the disc, the eye is *emmetropic* or *very slightly myopic*. (*Vide* explanation, p. 25.)

Indication 2.—If he see the image of the disc and its vessels moving in the *same* direction as, or *with*, his own head, the patient is *hypermetropic*. (*Vide* p. 28.)

Indication 3.—If the vessels in *one meridian only* are visible, and these move *with* the observer's head, there is *hypermetropia* in one meridian only, viz., in that at right angles to the one in which the vessels are visible, etc. = *simple hypermetropic astigmatism.* (*Vide* explanation, p. 28, and compare with Chap. V.)

Indication 4.—If the image of the disc and of the vessels appears to move in a direction *opposite* to, or *against*, that of the observer's head, the eye is *myopic.* (*Vide* p. 28.)

Indication 5.—If the vessels are seen in *one meridian only*, and appear to move *against* the direction of movement of the observer, there is *myopia* in the meridian at right angles to that in which the vessels are visible = *simple myopic astigmatism.* (*Vide* p. 28 and Chap. V.)

Indication 6.—If the vessels are seen moving in one direction in one meridian, and in the opposite direction in the other meridian, according to the accommodation of the observer and his distance from the patient, there is *mixed astigmatism.* This condition is, however, not easily detected by the direction of movement of the vessels.

Indication 7.—If, instead of the vessels of the disc moving evenly and regularly, they move slowly across the centre of the pupil, but rapidly and irregularly towards the periphery, giving the appearance of rotating bent spokes of a wheel, there is *irregular astigmatism.*

EXPLANATIONS.

For many points in the following explanations, and especially in those relating to the change in size of the disc (Chap. X.), I am indebted to my friend Dr. G. A. Berry.

Of all the rays (*vide* Figs. 6 and 7) which diverge from any single point (*a* or *b*) of the fundus one only (o′ or o) passes without deflection through the centre of the crystalline lens. As many of the remainder as the size of the pupil will allow pass out in a cone of rays having a certain relation, according to the refraction, to the ray just mentioned. In order to get a view of any part of the fundus, it is necessary that rays from *both* extremities of such portion should come to a focus on the observer's retina.

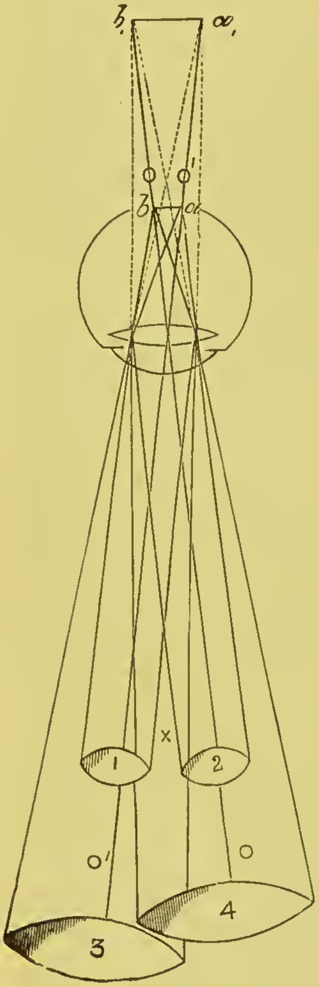

FIG. 6.

In *emmetropia* (Fig. 6), the rays which issue from the extremities *a* and *b* of the disc emerge as two cylinders (1 and 2) of *parallel* rays, taking the same direction respectively as those (o′ and o) which from the two extremities *a* and *b* pass through the centre of the lens. There are thus parallel rays in two cylinders, one from either extremity of the disc, emerging from the pupil and soon diverging from each other. They thus leave between them an area x, in which there are no rays from these two points. If the observer's eye be situated in this space, it is evident that he cannot get an image of the *whole* disc. He will, however, receive *parallel* rays from some luminous *point* of the disc, or even cylinders from two very contiguous points may run so closely together that, on entering the observer's eye, they might *theoretically* form an image of the space between them. *Practically*, however, such an image is rarely, if ever, obtained, because the *absolute* suspension of accommodation necessary for its production is scarcely to be met with. We may therefore assume that for practical purposes no details of the fundus are visible with the mirror alone at some distance, and that therefore in *emmetropia* the image of the disc is *blurred*.

In *hypermetropia* (Fig. 6) the rays issuing from the extremities *a* and *b* of the disc emerge from the pupil as two cones (3 and 4) of rays, which appear as if diverging from points $a_{,}$ $b_{,}$, situated behind the eye on prolongations backwards of the rays o′ and o respectively, which from *a* and *b* pass through the centre of the lens. By the union of the rays thus prolonged back, we get an *erect* image $a_{,}$ $b_{,}$ of the disc *a b*. (For the distance of this image behind the eye, *vide* p. 7, note to definition 6.)

The cones 3 and 4 being formed of diverging rays, separate from each other only at a considerable distance from the eye. Some of the rays from each extremity of the disc—or, at any rate, those from two fairly distant portions of the same—will enter the observer's pupil, and, with the exercise of sufficient accommodation to overcome their divergence, will meet on his retina.

An object may be supposed as situated at the points whence appear to issue the rays entering the eye. The object therefore which the observer here appears to see is the *erect image* of the disc. Since the object thus apparently seen is *further* from the observer than the pupil, with which it is, though perhaps unconsciously, compared, it seems to move with the observer's head. (*Vide* explanation below.)

In *myopia* (Fig. 7) the rays issuing from the extremities *a b* of the disc emerge as two cones of rays, which converge to points *a′ b′* on their secondary axes, o′ o, respectively, thus forming in front of the eye an *inverted* aerial image of the disc. If the observer be nearer the eye than where these rays unite, he will not get any image of the disc, since he receives only *convergent* rays which cannot come to a focus on his retina. If he, however, be far enough removed he will see the inverted image *a′ b′* of the disc. The rays having converged to form this image, now cross and reach his eye, diverging (3 and 4) from the aerial image as if proceeding from an illuminated object placed at the same distance in front of the patient's eye.

The aerial image thus seen, being *nearer* the observer than the patient's pupil, moves against the observer's head. (*Vide* the following explanation.)

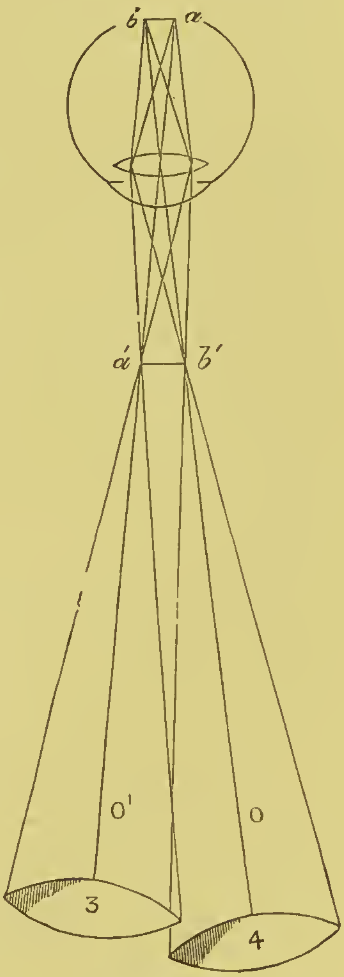

FIG. 7.

The apparent movement of the image of the disc is easily explained when we remember that this image occupies a position further from the observer than the patient's pupil in H, and nearer to him than the pupil in M. This may be illustrated by holding two pencils vertically, one behind the other. If we suppose the *further* one to represent the image of the disc, and the near one the pupil, we have the respective positions of these objects in H. If, then, while moving the head laterally, we fix the eye on the *further* pencil, we find that this latter comes to be placed on the same side of the near one as that towards which we move. It *appears* therefore to travel *with* the observer.

If, however, we suppose the *near* one to represent the image of the disc and the further one the pupil, we have their respective positions in M. Then, on moving the head laterally, while regarding the *near* pencil, it will be seen that this latter comes to be placed to the *left* of the further one when we move to the *right*, and *vice versâ*. It *appears*, therefore, to travel in a direction *opposite* to that of the observer.

The same explanation as that just given for the whole disc will apply also to vessels seen in different meridians.

In *simple astigmatism* we do not see vessels *at right angles* to the *emmetropic* meridian, because rays from their transverse planes (Chap. V., p. 16) passing through the emmetropic meridian will (as was seen for simple emmetropia) not be visible. Whereas rays from the transverse planes of vessels at *right angles* to the myopic or hypermetropic meridian will, by passing through this meridian, produce in the former case an inverted, and in the latter an erect, image of the vessels. These follow the same rules of movement as in simple myopia and hypermetropia respectively.

In *compound myopic astigmatism*, if the observer use his accommodation, vessels at *right angles* to the *most* myopic meridian will be distinctly seen much *closer* to the patient's eye than will those in the opposite meridian. Rays from the transverse planes of the former converge and form an inverted image much sooner than do those from the latter, just as in high degrees of simple myopia.

In *compound hypermetropic astigmatism* we find that for the vessels at *right angles* to the *most* hypermetropic meridian more accommodation is required at a given distance from the eye than for those in the opposite meridian. A greater extent of the former than of the latter vessels is, however, at the same time visible. Rays from the former are more divergent, and the cones take longer to separate (*vide* Fig. 6).

In *mixed astigmatism* images of the vessels *may* be seen sometimes inverted, and at other times erect, according to the meridian through which the rays emerge, and varying with the observer's accommodation. The details are more visible than in emmetropia, but are nevertheless very *indefinite*.

CHAPTER IX.

RETINOSCOPY (KERATOSCOPY).

By means of what was, unfortunately, called "Keratoscopy," we have a useful method of diagnosing errors of refraction with the ophthalmoscope mirror alone; and, what is perhaps more important, we can correct them with ordinary trial lenses quite independently of aid from the patient. This plan is particularly valuable where it is impossible to obtain complete steadiness of the eye under examination, as well as the *certainty* of relaxation of the observer's own accommodation. Without these conditions the estimation of refraction by the ophthalmoscope, as described in Chap. XI., is quite impracticable. As long ago as 1864 (*vide* "Anomalies of Refraction and Accommodation of the Eye," Donders, p. 490) Sir W. Bowman drew attention to "the discovery of regular astigmatism of the cornea, and the direction of the chief meridians, by using the mirror of the ophthalmoscope. . . . The area of the pupil then exhibits a somewhat linear shadow in some meridians rather than others."

Dr. Cuignet, of Lille, seems to have first systematized this method of examination, and, in 1874, published his conclusions in an article entitled "Keratoscopy."

Dr. Parent, of Paris, published an article on this method of examination in the *Recueil d'Ophthalmologie* for February and July, 1880, and Dr. Forbes has drawn attention to the subject in the *Oph. Hosp. Reports*, vol. x. For valuable information concerning the theory of keratoscopy the reader may be referred to Dr. Charnley's article in the *Oph. Hosp. Reports*, vol. x., part iii. Whilst for additional information respecting its mode of application, a reference to the *British Med. Journal* for January 16, 1886, may prove useful.

The appearances to be described are due to the play of light and shade upon the *retina*, and are varied in each case by the refractive condition of the eye through which the rays of light reach, and issue from, the retina. Though the cornea, by means of its different curvatures, undoubtedly influences the appearances met with, yet, since it only acts as one of the refractive media, it was considered preferable to discontinue the use of the misleading word "Keratoscopy," and adopt, as suggested by Dr. Parent, the term "Retinoscopy."

Rays of light from a distant lamp falling on a *concave* mirror, issue from the latter convergingly, and, crossing where they form an image of the lamp in front of the mirror, again diverge.

If in front of a screen we place a convex lens at such a distance that diverging rays from a concave mirror are brought to a focus exactly on the screen, there is formed the smallest and brightest possible image of the lamp, and the most sharply defined and densest surrounding shadow. If, then, we alter the position of the lens, it is found that the further it is removed from the point just mentioned—either towards or away from the screen—the *larger* becomes the area of light and the *feebler* is the illumination.

The increasing circles of diffusion render indistinct the line of demarcation between light and shade, and cause the latter to appear fainter. If, with the lens at different distances from the screen, the mirror be variously rotated, the area of light and shade will be seen, in *every* position of the lens, to move on the screen in a direction *opposite* to, or *against*, that in which the mirror is rotated. If we replace the screen and lens by the retina and dioptric system of the eye (Def. 1, p. 6), we have precisely similar results. The area of illumination on the *retina* in *all* states of refraction really moves in a direction *opposite* to that in which the mirror is rotated. But since this illuminated portion is seen through the transparent media of the eye, the *apparent* direction of its movement will be influenced by the refraction of the eye under examination.

In the practice of retinoscopy, atropine certainly renders material assistance, and without the aid of either it or homatropine perfectly accurate results cannot be obtained. With complete paralysis of the accommodation, however, and in the absence of complications in the media, it should be possible to obtain results well within 0·5 D. of the actual refraction. The observer should be seated opposite to, and 1 m. 20 cm. away from, the patient. The lamp should be placed somewhat posterior to, and above, the patient's head. The eye which is not under examination should be carefully shaded by a screen, while the rest of the room should be rendered as dark as possible. The mirror used may be concave or plain. The concave mirrors in general use are of 22 cm. focal distance, and the following appearances are those met with in using such an instrument. If a plane mirror be employed, the appearances will be the reverse of those here described. Should the observer not be emmetropic, the actual movement of the shadows is not thereby affected. But, as the just and definite appreciation of this movement is of the utmost importance, it is necessary that any error of refraction on the part of the observer which interferes with this definiteness—and it need not be much—must be corrected. The patient should look at the sight-hole in the mirror, while the reflected light is thrown into his eye, so that retinoscopy is effected in his visual axis.

We then see in the pupillary area a bright image of the illuminated portion of the retina. If the mirror be now rotated around its various diameters, we shall see:

1. A more or less linear shadow passing across the pupillary area.

2. That in simple ametropia this shadow travels along that meridian of the eye parallel to which the mirror is rotated.

3. That the *edge* of the shadow is at *right angles* to the meridian along which it travels.

The direction of the movement of the shadow indicates the refractive condition of this last-named meridian.

If, for example, the mirror be rotated around its vertical meridian from right to left, or left to right—*i.e.*, parallel to the horizontal meridian of the eye—the shadow will have its edge vertical, will travel in a horizontal direction across the area of the pupil, and will indicate the refraction of the horizontal meridian of the eye.

In astigmatism, the two principal meridians (p. 8) may be oblique. Then, even though the mirror be rotated parallel to the horizontal or vertical meridian of the eye, the shadow may be seen to move rather in a direction parallel to one or other of the oblique meridians. This indicates that retinoscopy should be practised by rotating the mirror parallel to these latter meridians (p. 37).

For any given meridian of the eye, the direction in which this shadow appears to move—*i.e.*, whether with or against the mirror—depends upon, and furnishes the chief means of diagnosing the nature of, the refraction of that meridian.

If the rays issuing from the observed eye do not cross before reaching the observer, an erect image of the illuminated and shaded portion of the retina is obtained. This image appears to move in the direction actually taken by the illuminated area upon the retina, viz., *opposite* to that in which the mirror is rotated. This is the case in H., E., and *low* M.

If, however, the issuing rays cross before reaching the observer, and form between him and the patient an inverted *aerial image* of the illuminated and shaded portion of the fundus, then, since the illuminated area on the *retina* really moves *against* the mirror, the *aerial image* of the same will appear to move in the same direction as, or with, the mirror. This appearance is met with in cases of M. of 1 D. ($\frac{1}{40}$) and upwards; for if the observer, with good power of accommodation, be seated as stated, 1 m. 20 cm. from the patient, then, where the M. = 1 D. ($\frac{1}{40}$) the aerial image, being formed at 1 m. (40 ins.) from the patient, and 20 cm. (9 ins.) from the observer, will be easily perceived by the latter. Still more is this the case where, with increasing M., the image is formed nearer the patient. If, however, the M. be less than 1 D. $(\frac{1}{40})$, the convergent rays from the eye either unite so close in front of the observer that no distinct image is received on his retina, or they meet behind him. In this latter case, the rays *not having crossed* before reaching the observer's eye, the image of the shadow is seen to move *against* the mirror. The way in which this condition is distinguished from H. or E. is explained further on (p. 38). If the eye under examination be to such an extent myopic that its far point is situated at the position of the image of the lamp—say 25 cm. in front of the mirror, or 95 cm. from the eye—then the diverging rays from this image will come to a focus exactly on the patient's retina (Def. 5, p. 7), and there form the smallest and brightest possible image of the lamp.

The further the departure from this degree, which we may call 1 D. $(\frac{1}{40})$ of M., the larger and feebler, as was seen on the screen, will be the illuminated portion of the retina.

The difference in the degree of luminosity of this reflex can be easily appreciated, and furnishes a means whereby the amount of error may be approximately estimated; so that, speaking generally, we may say, the feebler the illumination, the higher is the ametropia. An attempt has been made to use for the same purpose the difference in intensity of the shadow, but the appreciation of this is difficult, and it therefore does not afford an altogether reliable source of information.

If from some distance, say 1 m. 20 cm., we examine an eye with the mirror alone, we find that the higher the H. or M., the smaller is the image which we obtain of the disc; so that in very high degrees we see not only the whole disc, but also some of the surrounding fundus in the pupillary area. In E., on the other hand, so large is this image that only a small portion of it is visible at one time. With equally rapid rotations of the mirror, then, the light would have to travel much faster over the large image of the latter than the small image of the former condition. This difference in the *rate* of movement in the various states of refraction was pointed out by my friend Dr. Charnley; it constitutes, especially when taken together with the *luminosity* of the image, probably the best of the means at our disposal for estimating by this method, without glasses, different *degrees* of ametropia.

In E. and the lower degrees of H. and M., so little is seen of the large image of the illuminated area and the surrounding shadow, that the small portion of the latter, visible at any one time in the pupillary area, appears approximately *linear;* while, although with the increasing degrees of H. and M., the nearly circular area of illumination on the retina also enlarges, yet so much diminished is the image of the same, that more of the circumference of the surrounding shadow is visible at one time in the area of the pupil; it appears, therefore, more *crescentic*, while it becomes at the same time narrower.

Taking, then, the direction of the movement as denoting the *kind* of error, and the rate of movement, degree of luminosity, and curvature of the shadow, as indicating approximately the *amount* of the same, we may summarize as follows:

1. If the image of the shadow appear to move in the direction in which the mirror is moved, and if the rapidity of

movement and curvature of the shadow are the same in all meridians, we have a case of *simple* M.

2. If the image of the shadow appear to move in the opposite direction to that in which the mirror is moved, and if the rapidity of movement and curvature of the shadow are the same for all meridians, we have to do with either H., E., or *low* M.

3. The *slower* the movements of the image, the *feebler* the illumination, and the more *crescentic* and narrower the shadow, the *higher* is the H. or M.

4. A *difference* in two opposite meridians either of the direction or rapidity of movement, or of the curvature of the shadow, indicates *astigmatism.* These two dissimilar shadows, moving at right angles to each other, either one vertically and the other horizontally, or both obliquely, indicate the position of meridians of greatest and least refraction.

The situation of the principal meridians can be ascertained by noting whether the movement of the shadow in one meridian (particularly when nearly over-corrected) is complicated with movement in another. When there is no such complication it is probable that in most cases retinoscopy is being practised in one of the principal meridians. This movement of the opposite shadow also takes place in eyes characterized by irregular astigmatism.

It must be carefully noted that the direction of movement of the *shadow*, as compared with the *mirror*, is the *reverse* of that of the *disc* or vessels as compared with the *observer's head* (*vide* Chap. VIII.).

The *amount* of error may easily be measured by ordinary trial lenses. A little practice soon enables one to make an approximate estimate of the refraction, and to start with a lens nearly correcting the ametropia. At first, however, it is necessary to proceed carefully by quarter dioptres from zero. It will be well to remember (p. 35) that in high degrees of ametropia the reflex is often so feeble that there is great difficulty in determining the direction of the shadow. This is, perhaps, best ascertained by putting up successively a strong convex and a strong concave lens (4 D. or 6 D.). One of these will probably so far correct the ametropia that the reflex becomes bright and the shadow discernible. The further correction is then easily accomplished. Again, in M. below 1 D. and in E., though the reflex is bright, there is no definite shadow movement. This condition is easily distinguished from the preceding, where the reflex is dull.

Suppose, now, that we have first to deal with a case where the shadow moves *against* the mirror, or where, with a bright reflex, there is no perceptible movement of the shadow. We then know that the eye has either H., E., or weak M. But as we cannot tell which is present, we place in front of the eye *convex* lenses increasing in strength till one is reached which causes the shadow to move *with* the mirror. As soon as this occurs we know that M. of 1 D. is present. If this result is obtained with the weakest glass used (+·25 D.), then this latter will account for 0·25 D. of the M., while the remaining 0·75 D. of M. must have already existed in the eye. In the same manner, if the weakest glass required to reverse the shadow were either +0·5 D., +0·75 D., or + 1 D., there must have previously existed in each of these cases respectively, 0·5 D. of M., 0·25 D. of M. or E.

On the other hand, if with + 1 D. the shadow still moves *against* the mirror, it shows that the eye is hypermetropic. If the weakest glass which reverses the movement is + 1·25 D., it shows that the H. is 0·25 D. Had the eye been emmetropic, the shadow would have been reversed by + 1 D., while if H. to the extent of 0·5 D. had been present, then the + 1·25 D. would not have over-corrected it by 1 D., and the shadow would not have been reversed. Similarly with the higher lenses. If + 4·5 D. were the weakest which reversed the shadow, it would show that artificial M. of 1 D. had been produced, and the H. over-corrected by 1 D. The H., therefore, really present would be 3·5 D.

In the class of cases just illustrated, then, where the original shadow moves *against* the mirror, the actual refraction is indicated by deducting + 1 D. from the weakest *convex* lens which causes the shadow to move *with* the mirror.

In the second place, suppose we have to deal with a case where the shadow moves *with* the mirror. From this fact, we know that there must be present M. of at least 1 D. (p. 34). We then begin with the weakest *concave* lens, and proceed by quarter dioptres till one is reached with which the shadow *ceases* to move with the mirror. As soon as this is the case, say, with the weakest lens we try, viz., − 0·25 D., it shows that there cannot now be 1 D. of M. left uncorrected. The original M. must therefore have been exactly 1 D. Had it been even as much as 1·25 D., then the − 0·25 D. would have left 1 D. of M. uncorrected, and the shadow would have continued to move with the mirror.

In the same way, if – 2·25 D. were the weakest glass with which the shadow ceased to move with the mirror, it would show that the original M. actually present was 3 D. This is evident, because with – 2 D. the shadow was still with the mirror, and therefore 1 D. of M. was left uncorrected, while with – 2·25 D. the shadow ceased to move with the mirror, and therefore there could not have been 1 D. uncorrected. In other words, the M. could not have been as much as 3·25 D.

We see, therefore, that in this latter class of cases where the original shadow moves *with* the mirror, the actual refraction is indicated by deducting + 1 D. from the strongest *concave* lens with which the shadow continues to move *with* the mirror.

This deduction of + 1 D. from a lens, whether it be convex or concave, has the same result as adding – 1 D. to it. The signs plus (+) and minus (–) as applied to the trial lenses are algebraic terms, and the addition or subtraction of them follows the ordinary rules of algebra. For the sake of uniformity and simplicity, it is better, as suggested by Dr. Casey Wood in the *Journal of Ophthalmology, Otology, and Laryngology* for 1889, that the same rule shall be made to apply to both convex and concave glasses.

If the same lens produces similar results for all meridians there is no astigmatism. But if, when the movement is reversed in one principal meridian, it retains its original direction in the other, this proves astigmatism to be present. Each of the two principal meridians must then be corrected separately. This may be effected by correcting the refraction in one principal meridian by a spherical glass, and then, leaving it in position, correcting it in the other by means of an additional cylinder at right angles to this latter meridian. A more convenient method, however, and one generally adopted, is to correct the refraction in each of the principal meridians by means of separate spherical lenses. The degree of astigmatism is indicated by the cylinder in the former method, and by the difference between the two sphericals in the latter plan.

Having by the above method measured the refraction, the V. may be tested by the glasses thus indicated. These will give the best results in the majority of cases. Some patients, however, see better with lenses rather weaker, others with them stronger than the retinoscopy results indicate. It will therefore be occasionally necessary to make some modification in the glasses thus found, and especially is this likely to be the case in myopia.

If the refraction is the same in all meridians, a spherical lens will suffice.

With only one meridian ametropic, a cylindrical lens, with its axis at right angles to this meridian, will be necessary.

When there is either H. or M. in both of the principal meridians, the least ametropic meridian is corrected by a spherical lens. An additional cylinder of the same sign, and equal to the difference in refraction between the two meridians, is then placed at right angles to the opposite meridian.

Where there is H. in one principal meridian, and M. in the other, the former is corrected by a *convex* spherical lens. An additional *concave* cylinder, equal to the difference in refraction between the two meridians, is then placed at right angles to the myopic meridian.

The glasses which give the best results while the patient is under atropine sometimes also give the best V. when the effect of that drug has passed off. In other cases, again, some modification may be necessary. A convex lens not infrequently requires reducing in strength. A concave lens seldom requires any alteration. With spherico-cylinders any modification necessary may almost invariably be effected by means of the spherical lens alone.

If the patient cannot be seen after atropine has passed off, allowance may be made for its action (*vide* Chap. XIII.) by deducting a certain convex lens (varying according to the amount which it is deemed advisable to allow for atropine) from the *spherical* glass of the spectacles with which best V. is obtained. If a preliminary trial with glasses is not possible, the deduction may be made from the figures showing the actual refraction. The same amount must be deducted from each meridian so that the relative refraction may not be altered.

When the glasses are to be worn constantly, it is a good plan to let the patient continue atropine once daily until he has begun to wear them.

In conclusion, it may be well to recapitulate some of the more important points :

1. The observer must always be seated at the same distance from the patient, viz., about 1 m. 20 cm.

2. The mirror may be concave or plane, but the indications are of course exactly opposite with the two mirrors.

3. The accommodation and the iris being paralyzed by

homatropine or atropine, a screen should be placed over one eye, and the patient should look at the sight-hole in the mirror.

4. The situation of the principal meridians should then be roughly ascertained, and the degree of refraction tested with glasses. It is more convenient to test each meridian separately, and with spherical glasses only in the first instance.

5. If the shadow move against the mirror, or if with a *bright* reflex there is no definite shadow movement, we have a case of E., H., or *weak* M.

6. If the shadow appear to move with the mirror, the eye is myopic.

7. To ascertain the actual refraction while the eye is still under atropine,

Deduct + 1 D.

(*a*) From the weakest *convex* glass which *reverses* the shadow if it originally moved against the mirror.

(*b*) From the strongest *concave* glass with which the shadow *continues* to move *with* the mirror if it originally had this direction.

8. The *feebler* the luminous reflex, and the *slower* the movement of the shadow across the pupillary area, the greater is the amount of ametropia.

To illustrate the method of working retinoscopy, a few examples of astigmatism are appended. The cross lines, which for the sake of simplicity are placed vertical and horizontal, represent the two meridians. The figures refer to the meridian at the end of which they are placed. Those in the first brackets indicate the retinoscopy results as measured by trial lenses. The figures in the second brackets denote the actual refraction, and are derived by deducting + 1 D. from the previous numbers, while those in the third brackets show a further deduction of + 1 D. for the action of atropine. The latter deduction does not at all imply that this is the amount which should always, or even generally, be deducted, but is merely given by way of illustration.

The glasses in the first brackets correspond to the actual refraction under atropine, as shown by the figures in the above-mentioned second brackets. The glasses in the second brackets show the deduction of + 1 D. for atropine, and correspond to the figures in the above-mentioned third brackets. This deduction may also be made from the *spherical* lens of the previous glasses, or of those with which best V. was obtained under atropine.

To prevent confusion, the following examples are given only in dioptric measurements.

The sign ⊃ means "combined with."

"G." = glasses.

Case I.—Simple hypermetropic astigmatism :

| (+ 2) (+ 1) (0)
—|— (+ 5) (+ 4) (+ 3) =G. (+ 1 *s.* ⊃ + 3 *c. vert.*) (+ 3 *c. vert.*).

This + 3 D. c. may at any rate be ordered for work, but sometimes in such a case normal distant V. is not obtained without adding − 0·25 D. s. or − 0.5 D. s.

Case II.—Compound hypermetropic astigmatism :

| (+ 3) (+ 2) (+ 1)
—|— (+ 5) (+ 4) (+ 3) =G. (+ 2 *s.* ⊃ + 2 *c. vert.*) (+ 1 *s.* ⊃ + 2 *c. vert.*).

Case III.—Simple myopic astigmatism :

| (− 3) (− 4) (− 5)
—|— (+ 1) (0) (− 1) =G. (− 4 *c. hor.*) (− 1 *s.* ⊃ − 4 *c. hor.*).

Case IV.—Compound myopic astigmatism :

| (− 3)(− 4)(− 5)
——— (+0·5)(−0·5)(−1·5). =G. (− 0·5 *s.* ○ − 3·5 *c. hor*)(− 1·5 *s.* ○ − 3·5 *c. hor.*).

In Cases III. and IV. it is most probable that the glasses found under atropine to be the best, as indicated in the first brackets, are those which would be ordered for permanent use without making any allowance for atropine.

Case V.—Mixed astigmatism :

| (+ 0·75)(− 0·25)(− 1·25)
— ——— (+ 3)(+ 2)(+ 1) =G. (+ 2 *s.* ○ − 2·25 *c. hor.*)(+ 1 *s.* ○ − 2·25 *c. hor.*).

Case VI.—Mixed astigmatism :

| (+ 1·5)(+ 0·5)(− 0·5)
——— (+ 4·5)(+ 3·5)(+ 2·5). =G. (+ 0·5 *s.* ○ + 3 *c. vert.*)(+ 2·5 *s.* ○ − 3 *c. hor.*).

Suppose that in this case the best V. was obtained, not by the glasses indicated in the first bracket, but by + 3 D. *c. vert.*, this would show that, under atropine, the vertical meridian was emmetropic, and the horizontal meridian hypermetropic 3 D., thus :

| (0)(− 1)
— ——— (+ 3)(+2).

After deducting + 1 D., therefore, for atropine from each meridian, as shown in the brackets, the final glasses would be + 2 *s.* ○ − 3 *c. hor.* The same result would be obtained by placing − 1 D. in front of the + 3 D. *c.*, thus : − 1 D. *s.* ○ + 3 D. *c. vert.*, but it is better to adhere to the rule of making the *spherical* glass *convex*.

CHAPTER X.

INDICATIONS AFFORDED BY MIRROR AND OBJECT LENS.

"INDIRECT METHOD."

THIS method of diagnosing hypermetropia and myopia was first pointed out by Mr. Hutchinson (*Ophthalmic Hospital Report*, vol. iv., p. 189), and Mr. Couper (*Medical Times and Gazette*, January 30, 1869) has shown how astigmatism may also be recognised by it. It is desirable that atropine should have been applied, for otherwise an alteration in the pupil may easily lead to the supposition that the disc has changed in size.

In this mode of examination the observer must place the object lens *as close as possible* to the patient's eye; then, keeping the optic disc steadily in view, he must gradually withdraw the lens to the distance of a few inches, when:

Indication 1.—If the disc remain the *same size* throughout, the patient is *emmetropic*. (*Vide* explanation, p. 47.)

Indication 2.—If the disc *diminish* in size on withdrawing the lens, the patient is *hypermetropic*, and the amount is proportional to the rapidity of diminution. (*Vide* explanation, p. 48.)

Indication 3.—If the disc *decrease* in size *in one meridian only*, the patient is *hypermetropic* in *that* meridian only = simple hypermetropic astigmatism.

Indication 4.—If the disc diminish in all meridians, but *more* in *one* meridian than the others, there is *hypermetropia* in all meridians, but the greatest is in that meridian which decreases most = compound hypermetropic astigmatism.

Indication 5.—If the disc *increase* in size on withdrawing the lens there is *myopia*, and the amount is proportional to the rapidity of increase. (*Vide* explanation, p. 49.)

Indication 6.—If the disc *increase* in *one* meridian only, there is *myopia* in that meridian alone = simple myopic astigmatism.

Indication 7.—If the disc increase in every direction, but *more* in *one* meridian than another, there is *myopia* in all meridians, but the greatest is in that meridian which increases most = compound myopic astigmatism.

Indication 8.—If the disc *increase* in *one* meridian, and *diminish* in the *opposite* one, there is *myopia* in the former, and *hypermetropia* in the latter = mixed astigmatism.

Explanation of Change in Size of the Disc.—These changes in size of the image of the disc will be evident on remembering that *the relative sizes of image and object are as their distances from the lens.* To find the distance of the image from the lens, we have the formula $\frac{1}{b} = \frac{1}{f} - \frac{1}{a}$ where b = the distance of the image from the lens, f = the focal length of the lens, and a = the distance of the object. In each of the following examples the focal length of the lens is 4 cm.

In *emmetropia* the rays issuing from the disc emerge from the eye *parallel*, as if proceeding from an object situated at an infinite distance (Def. 3, p. 6). It is of this supposed object that we get an image by means of a convex lens held in front of the patient's eye. It matters not, therefore, where this lens is held, the *parallel* rays from the object will always unite to form an image on the opposite side of the lens at its principal focus (Chap. I., *b*, p. 3). The relative distances of image and object from the lens remaining *constant*, the size of the image of the disc in emmetropia does not vary with movements of the lens.

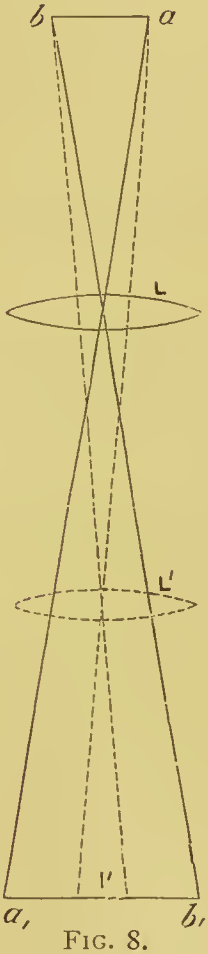

FIG. 8.

In *hypermetropia* (Fig. 8),* rays issuing from the disc emerge from the eye as if proceeding from an object *b a* situated at a certain distance behind it (Def. 6, p. 7).

It is of this supposed object, *b a*, that we gain an *image a' b'* or I' by means of a lens held in front of the patient's eye.

Suppose this lens L to be at 6 cm. from the object, we find by the formula that the distance of the image *a' b'* is 12 cm. $\left(\frac{1}{b} = \frac{1}{4} - \frac{1}{6} = \frac{1}{12} \text{ or } b = 12\right)$.

If we now withdraw the lens from the object (and also from the eye) till it is 12 cm. from the former, as at L', the distance of the image I' (between the dotted lines) will then be 6 cm. $\left(\frac{1}{b} = \frac{1}{4} - \frac{1}{12} = \frac{1}{6} \text{ or } b = 6\right)$.

The ratio of the distance of the image from the lens as compared with that of the object from the lens being *greater* in the first case than in the second, so is the size of the image. In *hypermetropia*, on withdrawing the lens from the eye the image of the disc *diminishes* in size.

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* In figs. 8 and 9 the distances of the lenses from the objects and images are drawn to scale, $\frac{1}{2}$ cm. = 1 cm.

In *myopia* (Fig. 9) rays from the disc emerge from the eye convergently, and form at a certain distance in front of it an inverted aerial image, *a b*, of the disc. This latter we have now to regard as the object O, whose image I or I′ we obtain by means of a convex lens L or L′ interposed between it and the patient's eye E. A lens thus placed intercepts the rays B*b*, A*a* (which, to avoid confusion, are the only ones shown, of all those) which converge towards the points *b* and *a* respectively of this object O. The rays, being thus rendered more convergent, produce an image I or I′, whose extremities will be bounded by the lines passing from either end respectively of the object O, through the centre of the lens L or L′.

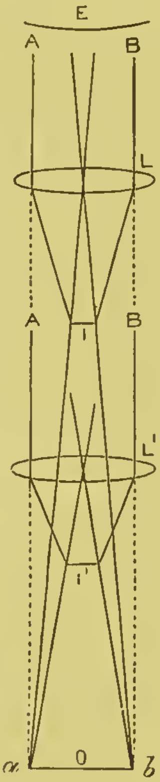

FIG. 9.

In this case, object and image are on the *same* side of the lens. The object here being on the opposite side of the lens from the direction in which the rays proceed, it is customary, in order that the same formula may hold good in all cases, to regard $\frac{1}{a}$ as a *negative* quantity. For the distance of the image from the lens then, we have the formula

$$\frac{1}{b}=\frac{1}{f}-\left(-\frac{1}{a}\right)=\frac{1}{f}+\frac{1}{a}.$$

If we first place a lens L 12 cm. nearer the eye than where the object o would be formed, we have the image I at 3 cm. from the lens $\left(\frac{1}{b}=\frac{1}{4}+\frac{1}{12}=\frac{1}{3}\text{ or } b=3\right)$. If we now withdraw the lens *from* the eye, *i.e.*, towards the object, till it is within 6 cm. of the latter, as at L′, the distance of the image I′ will be nearly 2 cm. $\left(\frac{1}{b}=\frac{1}{4}+\frac{1}{6}=\frac{5}{12}\text{ or } b=\text{nearly } 2\right)$. But as the ratio of the distance of the image from the lens, as compared with that of the object from the lens, is greater in the second than the first of these examples, so is the size of the image. In myopia, therefore, on approaching the lens to the eye the image diminishes in size, and on *withdrawing* it from the eye, the image *increases*.

The above explanation holds good for *myopia* only so long as the lens is not withdrawn beyond the far point of the eye *plus* its own focal distance; for *hypermetropia* only so long as the focal power of the lens is greater than the degree of hypermetropia. The exception to this latter condition does not occur in practice if a lens of 3 inches focus be used, and need not therefore be considered. In the case of very high degrees of myopia, however, if the lens be further from the eye than the aerial inverted image of the disc *plus* its own focal distance, an erect image of the disc is formed between the lens and the observer, the variations in size of which are subject to the same rules as those described for the inverted image in hypermetropia.

CHAPTER XI.

ESTIMATION OF THE REFRACTION BY MEANS OF LENSES IN THE OPHTHALMOSCOPE.

In estimating refraction by this method the patient and observer must be seated side by side facing in opposite directions. Their heads and the lamp should be on the same level, the latter being placed on the same side of the patient as that under examination, a little out from, and slightly behind the position of, the patient's ear. If now the heads be inclined laterally towards each other, the eyes of the corresponding sides will come opposite one another, while the noses and mouths will be left free for breathing. By this means the sight-hole of the mirror may generally be placed in the position which, when ordered, the glasses will occupy ; the distance of these from the eye need therefore not be taken into consideration when prescribing from measurements thus obtained. Should it, however, be undesirable to approach thus close, the distance from the patient must be taken into account, and the glasses ordered will have to be somewhat *weaker* in *myopia* and *stronger* in *hypermetropia* than the lens necessary to see the fundus would indicate. In estimating refraction by the ophthalmoscope it is absolutely essential that the accommodation of both patient and observer be *completely* suspended. In order to secure the former we must place the patient opposite a dark wall or curtain, or employ atropine. For the observer voluntarily to relax his own accommodation while looking at an object so near to him as the patient's eye, requires much practice. The best way of overcoming the difficulty is to regard the fundus as situated some hundreds of yards distant. This habit may be acquired by looking alternately at a spot on the window-pane and then at some remote object, or by gazing vacantly at the page of a book until the type disappears; then, having noticed the sensation produced on thus relaxing the accommodation, endeavour to induce the same condition while observing a fundus.

In the following indications it is of course necessary that the observer be fully cognizant of the state of his own refraction, and in the following cases he is supposed to be emmetropic (if not, *vide* note, p. 54). With accommodation, then, entirely suspended, the eye of the emmetropic observer is adjusted for *parallel* rays.

Indication 1.—If, therefore, he can see distinctly the details of any fundus, the rays issuing thence must be *parallel* and the eye *emmetropic*.

NOTE.—Though this appears to contradict what has been said concerning seeing the disc in emmetropia (Chap. VIII., p. 25), yet we must remember that when *close* up to the patient's pupil, the observer *does* receive rays from the two extremities of the disc. Moreover, if the observer endeavour to accommodate for the patient's eye, he will find it impossible to do so, since, if he is as close as he should be, the latter, as explained by Mr. Power, is nearer to him than his near point. The effort is therefore not maintained, and as when the accommodation is partially suspended the disc begins to appear, the former is unconsciously *altogether* relaxed and a distinct view is obtained.

Indication 2.—If, however, the details of the fundus cannot be seen except by the intervention of a *concave* lens, this proves the patient to be *myopic.* The converging rays from such an eye (Def. 5, p. 7) require a concave lens to render them parallel for perception by the emmetrope. The strength of the lens which effects this change of direction indicates the degree of M., for it is evident that the same lens which renders parallel the converging rays issuing from the retina will bring parallel rays to a focus on the retina of the same eye.

Indication 3.—If, again, with suspended accommodation the details of the fundus are not visible without the aid of a *convex* lens, this indicates the patient to have *hypermetropia.* The diverging rays from a hypermetropic eye require a convex lens to render them parallel. The strength of the lens necessary for this purpose denotes the amount of H., for the lens which renders parallel, ray's proceeding from a retina will also bring parallel rays to a focus on the same retina.

Indication 4.—If the vessels in one meridian are seen without any lens, while a convex or concave lens is required for those in the other meridian, it is a case of *simple* astigmatism. The emmetropic meridian is the one at *right angles* to the vessels seen without any lens (Chap. V., p. 16).

Indication 5.—If for the two opposite meridians we require either two convex or two concave lenses of *unequal* power, we have to deal with a case of *compound* astigmatism—hypermetropic or myopic respectively. The greatest error of refraction in each case is at *right angles* to the vessels for which the strongest lens is necessary.

Indication 6.—If for vessels in one meridian we require a *convex* lens, while for those in the other a *concave* is necessary, it indicates *mixed* astigmatism. The hypermetropic meridian is at *right angles* to the vessels seen best with a convex lens; and the myopic to that for which a concave lens is necessary.

In all these forms of astigmatism, then, we see that the lens which, with *absolutely* suspended accommodation, gives the best view of vessels in *one* meridian, measures the amount of error which exists in the *opposite* meridian.

NOTE.—Should the observer not be emmetropic, yet, if he correct his own error with spectacles, he is in the same position as an emmetropic observer. If he, however, prefer to estimate refraction without his glasses, he must make an allowance for his defect by means of the lenses behind the sight-hole of the mirror. To see the details of an *emmetropic* fundus, a hypermetropic or myopic observer *starts* with a lens corresponding to the amount of his own error. For any particular fundus, therefore, the glass required by him must be, to the extent of his H. or M., *more* convex or concave respectively than would be necessary for an emmetrope to see the same fundus. Consequently the *patient* will always have that amount *less* H., and *more* M.; or *more* H. and *less* M. respectively than the same lens would indicate if the observer were emmetropic; we have then the

RULE II. That the observer must *deduct* the amount of his own H. or M. from the lens which enables him to see distinctly any particular fundus.

TABULAR VIEW OF THE STATE OF REFRACTION AS INDICATED BY THE VARIOUS METHODS.

TEST TYPES.			OPHTHALMOSCOPE.				
			MIRROR ALONE.				
DISTANT VISION.	NEAR VISION.	RAYS IN FAN.	Movement of *image of O. D. and vessels* compared with *Head.*	Movement of *Image of Shadow* compared with *mirror.*	INDIRECT METHOD. Image of O. D. on *withdrawing* lens.	Lens necessary in Ophthalmoscope *without accom.*	REFRACTION.
$\frac{6}{6}$ $\left(\frac{20}{20}\right)$	Sn. 1, 5 in. to 20 in.	All clear.	Red reflex only.	*Against;* same rate in all meridians.	Constant in Size.	None.	E.
By accom. may be $\frac{6}{6}$ but is often less.	Sn. 1, or larger, but *not close up.*	All clear *by accom.*	Erect; moves *with.*	*Against;* same rate in all meridians.	Decreases.	Convex.	H.
Not $\frac{6}{6}$	Sn. 1, (or 2) but not so far off as distance marked.	None.	Inverted; moves *against.*	*With;* (except low M.) same rate in all meridians.	Increases.	Concave.	M.
Not $\frac{6}{6}$	Larger series (or smaller with difficulty).	*One* clear at *rt. ang.* to *Em.* meridian.	Vess. parallel to *Em.* merid. move *with.*	In two opp. merids. Both *against* at diff. rates.	Decreases in *one* meridian only.	Vess. Parl. to Em. merid. = + Vess. Parl. to Hc. merid. = O.	H. As.
			Vess. parallel to *Em.* merid. move *against.*	In two opp. merids. one *against*, one *with.*	Increases in *one* meridian only.	Vess. Parl. to Em. merid. = — Vess. Parl. to Mc. merid. = O.	M. As.
Variable.	Larger only.	Varying with accom.	Vess. at diff. distances, *all* move *with.*	In two opp. merids. Both *against* at diff. rates.	Decreases all round, but *more* so in *one* meridian.	Two diff. *convex.*	C.H. As.
		None.	Vess. at diff. distances, *all* move *against.*	In two opp. merids. Both *with* at diff. rates.	Increases all round but *more* so in *one* meridian.	Two different *concave.*	C.M. As.
		One at *rt. ang.* to Hc. merid. *by accom.*	Some vess. *with* and others *against.*	In two opp. merids. one *against*, one *with.*	Decreases in *one* but increases in *opp.* meridian.	One merid. + Opp. merid. —	Md. As.

Abbreviations:—E. Emmetropia; M. Myopia; H. Hypermetropia.
H. As. Simple Hypermetropic Astigmatism; C. H. As. Compound Hypermetropic Astigmatism.
M. As. „ Myopic „ C. M. As. „ Myopic „
Md. As Mixed Astigmatism; Vess. Vessels; Parl. Parallel; Diff. Different; O. D. Optic Disc.

CHAPTER XII.

TEST GLASSES AND TYPES AS APPLIED TO THE ESTIMATION OF REFRACTION.

WHEN ascertaining with the distance types the state of the patient's refraction, we must be absolutely certain that his accommodation is completely relaxed. In myopes it generally is so, but in hypermetropic and astigmatic patients it is frequently a troublesome and misleading factor. If, from the varying and inconsistent statements of the patient, it is suspected that he does not relax his accommodation, he may do so more easily if he close his eyes between each change of glasses, not opening them until the fresh ones are *in situ*. Another method of assisting the patient is to let him put on a pair of + 4 D. glasses for ten or fifteen minutes, and then, without removing, gradually neutralize them by stronger and stronger concave lenses placed in front, until those are found with which the patient can see in the distance as well as without any glass. The *difference*, then, between the concave lens thus required and + 4 D. ($\frac{1}{10}$) gives the manifest hypermetropia.

If, however, there is any uncertainty as to the accommodation being relaxed, it is better, even in myopes, to have recourse to atropine. In all cases each eye must be tested separately.

One caution must be especially borne in mind, viz., *never* in any doubtful case to commence testing vision with *concave* glasses, for to see with such lenses it is necessary for all, except those whose myopia is equal to or less than the glasses being used, to employ their accommodation, and when once called into activity, this is not easily suspended.

Let the patient be placed at 6 m. (20 ft.) from the types. We have already seen what, with test types, are the indications of emmetropia and simple presbyopia (p. 21).

HYPERMETROPIA.

If the patient read $\frac{6}{6}$ $(\frac{20}{20})$ perfectly without glasses, still *this fact does not exclude the presence of hypermetropia*, the presence of which is proved if he can read the distance types as well with as without *convex* lenses. The *strongest* glasses which are thus tolerated indicate the degree of *manifest* hypermetropia (Hm.), and they *at least* must be ordered for close work. In young adults, and in the higher degrees of H., we must for this purpose even give glasses 1 D. or 1·50 D. $(\frac{1}{40}$ or $\frac{1}{24})$ stronger. In order to give rest to the ciliary muscle, it is advisable for constant use to prescribe at any rate the glasses which correct the *manifest* hypermetropia. If the H. be measured under atropine, the glasses ordered must be 1 D. (or possibly even 1·50 D.) *weaker* than the total amount thus found to exist (*vide* Chap. XIII.). These should be suitable for all purposes, though for distant V. weaker ones are sometimes necessary.

The amount of hypermetropia which is apparent only after atropine is applied is called the latent hypermetropia

(Hl.), and, added to the Hm., gives the total hypermetropia (Ht.). The Hm. steadily increases and the Hl. steadily decreases as age advances, till at last the Hm. = Ht.

MYOPIA.

As we have already stated (Ind. 3, p. 21), if the patient can read the *finest* type to within 4 or 5 inches of his eye, while at the same time his distant V. does not exceed $\frac{6}{24}$ ($\frac{20}{70}$), and is probably not $\frac{6}{60}$ ($\frac{20}{200}$), he is *myopic*. An indication of the degree may be obtained by observing the furthest point at which either of the smallest types can be read. Provided it be nearer than that for which it is marked, the distance of this point gives the focal length of the lens required to neutralize the M.

E.g.:—If Sn. 1 be legible only as far off as 12 cm. (5 ins.), the M. is measured by the concave lens having this focal length, viz., 8 D. ($\frac{1}{5}$). Or, again, if No. 4 Sn. marked for 1 D. (40 ins.), can be read only at 50 cm. (20 ins.), the M. = 2 D. ($\frac{1}{20}$).

In testing the distant V. with glasses, we commence with the *weaker* concave glasses, and work up to the stronger. In doing this, we cannot be too careful in ascertaining which is the *weakest* glass that neutralizes the M. and gives the best V., whether this be $\frac{6}{6}$ ($\frac{20}{20}$) or less. The glass thus found gives the measure of the M., and may generally be ordered for distant V. Such glasses may also be given for close work when, *with good accommodation*, the M. does not exceed about 6 D. or 8 D. ($\frac{1}{6}$ or $\frac{1}{5}$). In most cases where the M. is higher, and in all where the accommodation is feeble, we must order *weaker* glasses for *close* work.

The strength of these may then be found in the following manner, viz.: From the neutralizing lens *deduct* the strength of the glass whose focal length equals the distance at which we wish the patient to work.

E.g.—With M. = 10 D. ($\frac{1}{4}$) we wish the patient to do work at 40 cm. (16 ins.). From 10 D. ($\frac{1}{4}$) we deduct, therefore, the lens whose focal length is 40 cm. (16 ins.), viz., 2·50 D. ($\frac{1}{16}$), and the glasses ordered will be 10 D. − 2·50 D. = − 7·50 D. $\left(\frac{1}{4}-\frac{1}{16}=\frac{1}{5\frac{1}{3}}\right)$.

ASTIGMATISM.

If the V. cannot be brought up to $\frac{6}{6}$ ($\frac{20}{20}$) with any *spherical* glasses, we probably have to do with a case of *astigmatism*. In dealing with this error, as with all others, each eye should be tested separately.

If, from the previous examination with the ophthalmoscope, we have diagnosed—

1. *Simple* astigmatism, we can proceed to test with the fan of rays. If our surmise has been correct, the patient should now see quite distinctly only the line at *right angles* to his emmetropic meridian (Chap. V., p. 16). If this line were vertical, it would therefore denote that the meridian *parallel* to it was either hypermetropic or myopic; we should then ascertain what cylinder, with its axis at *right angles* to this latter meridian, is required to correct it—*i.e.*, to render clear the horizontal line. If the correction thus found gives V. = $\frac{6}{6}$ ($\frac{20}{20}$), it may generally be ordered for constant use (p. 44); but if it do not, then, as where none of the rays are distinct, and more particularly if first one, then another,

is most clearly seen, we must not hesitate to employ atropine.

It matters not now whether we have to deal with—

2. Compound or mixed astigmatism. We have merely to ascertain what *spherical* lens clears *one* of the rays, and then, leaving this glass *in situ*, try what cylinder, with its axis at *right angles* to the line thus cleared, renders equally distinct the ray in the opposite meridian. This spherico-cylindrical correction, *after due allowance for atropine* (Chap. XIII.), is ordered for constant use.

3. Another less scientific, though practically useful plan, is to substitute the test-types for the lines, and having found the spherical lens which gives the best V., try what additional cylinder is required.

4. If each meridian has been measured separately with spherical glasses either for the fan, or in the ophthalmoscope for the fundus, we shall have to calculate what sphericocylinder is required. (*a*) For *compound* astigmatism, we generally give the spherical lens which corrects the meridian of least error, and then add the cylinder (concave for myopic, and convex for hypermetropic astigmatism) whose strength equals the difference between the two meridians. (*b*) In *mixed* astigmatism, the difference between the sphericals also gives the degree of astigmatism and the strength of the cylinder required. It is advisable, in ordering this combination, to prescribe the spherical lens convex, and the cylindrical lens concave.

E.g.—With vertical meridian myopic 2 D. ($\frac{1}{20}$), and the horizontal meridian hypermetropic to the same extent, the *difference* between them = 4 D. ($\frac{1}{10}$). If, therefore, we give

+2 D. spherical ($\frac{1}{20}$), we must add −4 D. cylindrical ($\frac{1}{10}$) with its axis *horizontal* (*i.e.*, at *right angles* to the myopic meridian; Chap. I., p. 4). But if we gave −2 D. spherical ($\frac{1}{20}$), we should require in addition +4 D. cylindrical ($\frac{1}{10}$) axis vertical. The action of atropine (Chap. XIII.) must of course be taken into account.

5. Another method of testing astigmatism is by means of Tweedy's optometer, of which, with the exception that the later instruments are marked in dioptres and inches instead of only in inches, he has published a description in the *Lancet* for October 28, 1876. The patient under atropine is made artificially myopic by a convex lens; a card with fine radiating lines is gradually approached to his eye until *one* line becomes quite distinct. The meridian at *right angles* to this line is then known to be the *least* refractive. The *concave* cylinder is found, which, with its axis at *right angles* to the line first seen, makes the line in the opposite meridian equally distinct. This shows that the latter meridian is now made as little refracting as the former. The distance at which the first line is seen indicates the kind and degree of the error for the *least* refracting meridian. A *spherical* lens correcting this is then ordered, and, in combination with it, the *concave* cylinder of the strength, and in the axis, which were found necessary to equalize the two meridians.

6. Retinoscopy. This is an exceedingly useful means of estimating astigmatism, since it is an entirely objective method, and places us in complete independence of the patient. It has these advantages over the estimation of the degree of astigmatism by the ophthalmoscope, that it is a

much easier method to practise, and that by means of it the refraction in the visual axis may be estimated. This is important, for the refraction in the visual axis has been shown to differ from that indicated in the optic axis. For directions, see Chapter IX.

PRESBYOPIA.

Though the patient does not require glasses for distant V., he may, as age advances, find it more and more difficult to read or work without them. This defect is called *Presbyopia*, and is caused chiefly by failure in the power of accommodation. A flattening of the crystalline lens sometimes accompanies it, and causes some hypermetropia, which has been called "hypermetropia acquisita." *Presbyopia* is *indicated* by a *recession of the near point*, and it is said by Donders to have commenced when this is further from the eye than 22 cm. (9 ins.), *i.e.*, than the focal length of a lens whose refracting power is 4·50 D. ($\frac{1}{9}$). As we have already seen (Chap. IV., p. 13), such a lens would, in *emmetropia*, bring rays from the near point to a focus on the retina in the absence of *all* accommodation.

The *difference*, then, between this lens and one whose focal length equals the distance of any given *receded* near point, denotes in all cases the amount of accommodation which is deficient, and the lens necessary to enable the patient again to read at 22 cm.

E.g.—With near point receded to 40 cm. (16 ins.), we must deduct from 4·50 D. ($\frac{1}{9}$) the lens whose focal length is 40 cm., viz., 2·50 D. ($\frac{1}{16}$), and have as the necessary lens

+2 D. $(\frac{1}{20})$—that is, if the patient wish to read and work at 22 cm. (9 ins.).

If no accommodation remain, and either hypermetropia or hypermetropia acquisita co-exist, the strength of the correcting lens must of course then be *added to* 4·50 D. $(\frac{1}{9})$, in order that such a patient may read at 22 cm. (9 ins.).

The following table gives, according to Donders, the glasses necessary for presbyopia in *emmetropia* at different ages.

AGE.	GLASS.	
	D.	ENGLISH INCHES.
45	1	$\frac{1}{40}$
50	2	$\frac{1}{20}$
55	3	$\frac{1}{12}$
60	4	$\frac{1}{10}$
65	4·50	$\frac{1}{9}$
70	5·50	$\frac{1}{7\frac{1}{2}}$
75	6	$\frac{1}{7}$
80	7	$\frac{1}{6}$

These are the glasses which enable an emmetropic patient to read at 22 cm. (9 ins.). We must, however, test each individual case, for the various patients prefer different distances at which to read or work. If either Hm. or M. be present, the amount of the former must be *added to*, and that of the latter *deducted from*, the lens here specified for any particular age.

This will be evident when it is remembered that a hypermetrope either has to use his accommodation, or, when not doing so, requires a convex glass to focus parallel rays on his retina. To work, therefore, at 22 cm. (9 ins.), he would need a glass to the extent of his Hm. stronger than an emmetrope of the same age, whose eye, when at rest, is adjusted for parallel rays.

A myope, on the other hand, requires a concave glass to focus parallel rays. Without a glass, and when not using any accommodation, his eye is adjusted for rays proceeding from his far point (p. 7); he therefore uses his accommodation only for distances within this range.

A myope, for instance, of 2 D. ($\frac{1}{20}$) needs no accommodative effort to see at 50 cm. (20 ins.). At this point the emmetrope already uses 2 D. ($\frac{1}{20}$) of accommodation. For any particular point, therefore, within this distance such a myope requires 2 D. ($\frac{1}{20}$) less accommodation than the emmetrope. At the age of fifty, when the emmetrope needs + 2 D. ($\frac{1}{20}$) with which to work at 22 cm., this myope would not require any glass for that purpose. At the age of fifty-five, when the emmetrope requires + 3 D. ($\frac{1}{12}$), this same patient would need only + 1 D. ($\frac{1}{40}$). It is thus seen how a myope may even require a *convex* glass for reading.

A myope who has worn neutralizing glasses for all purposes requires weaker glasses for close work as age advances, and, as was just seen, may require convex glasses for this purpose. Where the M. is 4·5 D. ($\frac{1}{9}$), presbyopia does not exist, for the p.p. (p. 13) cannot recede beyond the p.r., which is at 22 cm. (9 ins.). Such patients, even in the absence of all accommodation, can see to read at 22 cm. without glasses, and similarly in higher degrees of M.

APHAKIA,

or *absence of lens*, as after cataract operations, involves loss of accommodation. If we replace the crystalline lens by a glass in front of the eye, so that parallel rays are focussed on the retina, we render the eye *practically emmetropic*. To enable such a patient to read at any specified distance, it is necessary merely to add to that glass the lens whose focal length equals the distance in question.

E.g.—If a patient requires + 13 D. $(\frac{1}{3})$ for parallel rays, and we wish him to read at a distance of 33 cm. (12 ins.), we add together 13 D. $(\frac{1}{3})$ and the lens whose focal length is 33 cm., viz. 3 D. $(\frac{1}{12})$, thus getting + 16 D. $\left(\frac{1}{2\frac{1}{2}}\right)$ as the necessary glass.

For cataract patients we order two pairs of spectacles. One for distant V., generally + 10 D. to + 13 D. $(\frac{1}{4}$ to $\frac{1}{3})$, and the other for reading, from + 15 D. to + 20 D. $\left(\frac{1}{2\frac{3}{4}} \text{ to } \frac{1}{2}\right)$ according to the previous state of the refraction.

A patient may be so myopic that, after removal of his cataract, parallel rays are focussed on his retina either without a glass or even by means of a weak concave lens.

Astigmatism frequently exists after cataract extraction, and as a rule its correction materially aids vision.

TO TEST THE GLASSES ORDERED.

Having ordered glasses, it often becomes necessary to ascertain whether those obtained by the patient accord with the prescription. This may be done in the following manner: If, whilst moving a *convex* lens to and fro in front of our eye, we look at some distant object, this latter appears to move in the *opposite direction.* A contrary effect is produced with a concave lens. A concave and a convex lens of equal strength neutralize each other, and there is no apparent movement of the object.

If, then, no movement is perceptible on applying a lens of the same strength as that ordered (though of an *opposite sign*), the glasses are correct. If the lens, however, is *not* of the same strength, we can ascertain the amount of error by finding the strength of that required to effect neutralization. In testing a cylinder, the neutralizing glass must be of the opposite sign, and the axes must coincide.

A spherico-cylindrical lens is tested by the neutralizing spherico-cylindrical combination, the axes of the cylinders being coincident.

CHAPTER XIII.

Atropine, Homatropine, Homatropine and Cocaine, Eserine—Alterations necessary in Measurements made under their Influence.

Although in estimating errors of refraction much may be accomplished without the use of atropine, yet in many cases it is not possible to arrive at an accurate result without employing this or some similar agent.

It is a mistake to suppose that a correct measurement of the error can be made in every case where the pupil is dilated. In doubtful cases no positive result can be reached without paralysis of the accommodation. For obtaining this condition three drugs are in common use, viz., atropine, homatropine, and cocaine; the two latter, in the majority of cases, being used in combination.

The chief factor to be considered in relation to the accommodation is the age of the patient. It is difficult to state precisely the ages at which definite strengths of the drugs must be used to produce complete paralysis. As a general rule, however, it will be found that in children and young adults the application of atropine (1 per cent.), thrice daily for a few days, is necessary. Sometimes even up to twenty-five years of age less will not suffice. From twenty-five to thirty homatropine and cocaine, if thoroughly applied, will generally be sufficient, though occasionally atropine (0·5 per cent.) may be required. After thirty atropine should not be used, and in patients over thirty-five it is very seldom necessary to paralyze the accommodation, though, if the pupil be small, its dilatation may assist the observer in making his estimation. After about twenty-five years of age the use of a mydriatic is to be avoided where any symptoms of glaucoma exist.

When used in cases of active accommodation, homatropine appears to render the accommodative efforts spasmodic and uncontrollable, so that the result is quite untrustworthy.

There is much difference of opinion as to how often and how long homatropine and cocaine should be used before it produces the desired effect. The following plan will generally be found effectual:

A drop of a mixture of homatropine (1 per cent.) and cocaine (2 per cent.) is instilled; then a drop of the same strength of homatropine solution alone is applied for about four times at intervals of ten minutes; and, finally, some more homatropine and cocaine mixture. Too much cocaine should not be applied, as it may disintegrate the corneal epithelium.

When the patient is well under the influence of the mixture, or of homatropine alone, a marked injection of the ciliary region is often noticed, and Mr. Phillips, Refraction Assistant at the Moorfields Hospital, tells me that he looks on this as an indication of the paralysis of accommodation.

The advantage of homatropine and cocaine over atropine lies in the fact that its effect, unlike that of atropine, passes away in from 24 to 48 hours, and consequently the risk due to the tension-raising influence of the mydriatic is much lessened. If there is any special reason for anxiety, or if work must be speedily resumed, a few applications of a 0·4 per cent. solution of eserine may be used to restore the power of the accommodation in a short time. (*Vide* Lang and Barrett in the *Medical Times*, July 18, 1885.)

Some authorities maintain that it is unnecessary to use atropine for myopes; but even though their accommodation may not be so well organized as in hypermetropes, yet there is not infrequently a spasmodic condition which determines an over-correction, and renders atropine necessary for correct estimation.

Where paralysis of the accommodation has been produced for the estimation of the refractive error, allowance must be made for this fact when ordering glasses.

According to DEF. 3 (p. 6), parallel rays *should* come to a focus on the retina of an emmetropic eye when the accommodation is completely paralyzed by atropine. Emmetropia, however, as thus defined, is rarely met with. An eye may have V. = $\frac{6}{6}$ ($\frac{20}{20}$), and the distant V. may be impaired by even the *weakest* convex lens, yet, when fully under atropine, it will generally be found that a *convex* lens is *now* necessary to obtain $\frac{6}{6}$ ($\frac{20}{20}$), *i.e.*, to bring practically parallel rays to a focus, so that a certain amount of accommodation *was* being exercised. That portion of the accommodation which can be overcome only by atropine is due to the *tone* of the ciliary muscle, and must always be taken into calculation when ordering glasses from a consideration of measurements of the refraction made under atropine. For *practical* purposes, we may consider that eye to be emmetropic which, when fully under the influence of atropine, does not require a stronger convex lens than 1 D. ($\frac{1}{40}$) to perfect the focusing of parallel rays.

In *hypermetropia* the convex lens which brings parallel rays to a focus when the eye is fully under atropine should *theoretically* convert it into an emmetropic eye. It is found, however, *practically* that, owing to hypertrophy of the ciliary muscle, patients with this error of refraction find great difficulty in relaxing their accommodation to anything like its fullest extent, and consequently the lens which brings parallel rays to a focus under atropine cannot be ordered for the same eye with its accommodation active. The increased convexity of the crystalline lens (produced by accommodation), added to the correcting lens just mentioned, renders parallel rays too convergent, and brings them to a focus in front of the retina. In hypermetropia, therefore, it is necessary to *deduct* from the measurement made under atropine at least 1 D. ($\frac{1}{40}$), and, in the cases of children and young adults, sometimes as much as 1·50 D. ($\frac{1}{24}$) on account of the tone of the ciliary muscle.

In *myopia* the concave lens which brings parallel rays to a focus on the retina of an eye under atropine may be found *too weak* for the same eye when *not* under atropine. The effect of the accommodation is to bring to a focus in front of the retina the rays which, under atropine, were focused upon it; in other words, the myopia is still sometimes uncorrected, and so requires a concave lens 0·50 D. ($\frac{1}{80}$) or 0·75 D. ($\frac{1}{50}$) stronger. But since the ciliary muscle of myopes is usually atrophied, the addition need not be equivalent to the deduction made in hypermetropia. We have therefore the

RULE III.—That glasses ordered for permanent use must, when *convex*, be 1 D. ($\frac{1}{40}$) or occasionally 1·50 D. ($\frac{1}{24}$) *weaker*, and, when *concave*, 0·25 D. ($\frac{1}{160}$) to 0·75 D. ($\frac{1}{50}$) *stronger* than is indicated by the measurements made under atropine. In M., however, this addition is seldom required.

The application of this rule may be exemplified by reference to a case of mixed astigmatism. If, under atropine, one meridian be hypermetropic, 2 D. ($\frac{1}{20}$) and the other myopic, 2 D. ($\frac{1}{20}$), the fully correcting glass would be *either* $-$ 2 D. s. $\bigcirc$ + 4 D. c. ($-\frac{1}{20}$ s. $\bigcirc$ + $\frac{1}{10}$ c.) *or* (preferably) + 2 D. s. $\bigcirc$ $-$ 4 D. c. (+ $\frac{1}{20}$ s. $\bigcirc$ $-$ $\frac{1}{10}$ c.). The glasses ordered for permanent use would be, in the first case, $-$ 3 D. s. $\bigcirc$ + 4 D. c. ($-$ $\frac{1}{12}$ s. $\bigcirc$ + $\frac{1}{10}$ c.), and in the second + 1 D. s. $\bigcirc$ $-$ 4 D. c. (+ $\frac{1}{40}$ s. $\bigcirc$ $-$ $\frac{1}{10}$ c.). In the latter example, by *deducting* 1 D. ($\frac{1}{40}$) from the convex spherical we at the same time practically add 1 D. to the strength of the concave cylinder (for it has thus *less* neutralization to perform); while in the first case, by *adding* 1 D. to the concave spherical we lessen the strength of the convex cylinder, since it now has more to neutralize.

In *mixed* astigmatism, then, by deducting from the strength of the spherical, we *increase* that of the cylinder, and by adding to the strength of the spherical, we *diminish* that of the cylinder.

In *compound* astigmatism, if we add to or deduct from the strength of the spherical, we at the same time increase or diminish respectively the correction for each meridian.

The calculations necessary for the action of atropine may thus be made for both meridians simultaneously, by means of the *spherical* lens alone.

When, under atropine, a simple cylinder gives the best results, this same lens will generally be most suitable for close work. The best ultimate distant V., however, may not be obtained without the addition of a weak concave spherical lens.

CHAPTER XIV.

AMBLYOPIA—MALINGERING AND ITS DETECTION.

IT need scarcely be mentioned in conclusion that there are many cases in which, though the error of refraction has been duly diagnosed, estimated, and corrected, yet there is no consequent improvement in vision. Such results may be found in old standing cases of strabismus, and sometimes in eyes in which no trace of disease can be discovered. Such eyes are said to be amblyopic. Others, again, without any error of refraction, may have defective vision owing to disease; with such, however, we have not here to deal. These pages have been intended merely to indicate the various modes of estimating and correcting errors of refraction; the reason why, after such correction, the vision is not improved must be ascertained by other means. Some patients, in whom we cannot find either disease or error of refraction, may simulate total or partial blindness. The latter may often be detected by holding in front of their eyes different pairs of convex, neutralized by their corresponding concave lenses. With these, thinking they are being aided, such patients may frequently be persuaded to read perfectly. Another method of detecting simulation, especially of *one* eye, is to hold in front of the *blind* (?) eye a prism with its base out or in, when, if there be an attempt (detected by the involuntary movement of the eye) to fuse the *double* images, it proves sight present in the eye in question. Another method is to put on the patient a pair of spectacles in which is a red glass for one eye and a green glass for the other. He is then asked what he can read of some red and green letters arranged alternately, and either placed on a blackboard, or else made of glass and suspended in a frame so that they are seen by transmitted light. If then the patient is able to read all the letters, it proves that he sees with both eyes.

Perhaps some of the statements made in these pages may have appeared somewhat too general, but it has been thought advisable not to confuse the beginner by enumerating all the possible and minor exceptions to the general rules.

If some such order of procedure as indicated in the preceding chapters were adopted, one would not, as is now frequently the case, see a beginner fall into the error of supposing that a patient is myopic because he reads $\frac{6}{6}$ as well with as without a *concave* lens. Nor would hypermetropia be diagnosed because Sn. 1 can be read with *convex* glasses.

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